Fortification Basics

Oils and Margarine

Rationale

Oils and fats, along with carbohydrates and proteins are major components of the human diet. Oils provide energy, fat soluble vitamins (vitamins A, D, and E), and essential fatty acids that are required for proper growth and development.

The production of vegetable oils (canola, corn, cottonseed, coconut, olive, palm, peanut, safflower, soybean, sunflower) is high throughout the world, and consumption (Table 1) is increasing, especially among the lower socioeconomic groups. A higher consumption of vegetable oils over animal fats is preferable because vegetable oils contain much less saturated fat than animal fats (Figure 1), and they contain no cholesterol.

Vegetable oils are suitable as vehicles for vitamins A, D, and E fortification, as the production and refining of the oils is a centralized process. As vitamins A, D, and E are fat soluble, they can be uniformly distributed in oil. The stability of vitamin A is greater in oils than in any other food and oil facilitates the absorption of vitamin A by the body. Vegetable oils are consumed by almost everyone; thus, it is possible to improve people's access to fat soluble vitamins through fortification.

Hydrogenation converts liquid vegetable oils into solid fats, such as margarine. The vitamin A and D content in margarine is negligible. However, fortification with these vitamins can make margarine an important source of these nutrients, as well as a source of energy.

Fortification with vitamin E may be important where the diet is high in polyunsaturated fatty acids (PUFA). PUFAs are long chain fatty acids with more than one double bond, which makes them susceptible to oxidation. The process of oxidation of fat in oils is the same as in cells.

- Food oils that are high in triglycerides can contain PUFAs, which produce hydroperoxyacids on oxidation resulting in a rancid odor in food.
- At the cellular level, oxidation results in the formation of free radicals, which have been shown to be associated with cancer and cardiovascular diseases (CVD); hence antioxidants are thought to be anticarcinogenic and cardiovascular protective.

Technologies now exist to add water soluble micronutrients including vitamin C, the B-complex, iron, and calcium to margarine.

Fortification Criteria

Fortification of vegetable oils and their derivatives (margarine, mayonnaise, etc.) with vitamins A, D, and E is technologically feasible. Crude vegetable oils are a rich source of vitamin E. Processing crude oil, however, can result in the loss of this vitamin; the extent of this loss is dependent on the processing method used. Vitamin E can be added to refined oil as a nutrient or as an antioxidant. Vitamin E antioxidants, such as alpha (α) tocopherol, prevent rancidity and protect other components in the oil susceptible to oxidation, including vitamin A, but it is not a good fortificant. Alfa tocopheryl acetate, in contrast, is stable, making it a good fortificant, but it has no antioxidant activity.

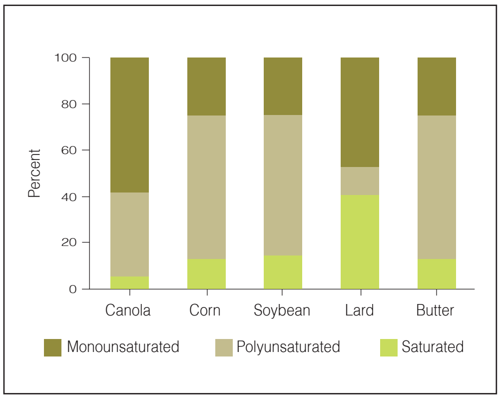
Table 2 shows that the range of vitamin A added to margarine in a number of countries varies between 3,180 and 45,000 IU/Kg, while

Table 1
Per Capita Vegetable Oil Consumption, and Percent Daily Energy Intake from Vegetable Oils in Selected Countries

Country	Consumption (g / day)	% Energy intake
Argentina	33	9
Brazil	27	9
Mexico	30	9
Costa Rica	35	11
Central Africa	12	5
Congo	34	12
Gambia	31	11
India	16	7
Indonesia	17	6
Philippines	12	4

Source: FAO.1991. Food Balance Sheets 1984-1986. Rome.

Figure 1
Fatty Acid Content of Different Vegetable Oils and Animal Fats



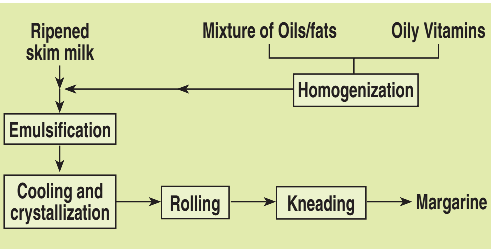
Source: Giese, J. 1996. Fats, Oils, and Fat Replacers. Food Technology. 50 (4): 77-84.

Table 2
Mandatory Fortification of Margarine with Vitamins A&D

Country	Vitamin A (IU/Kg)	Vitamin D (IU/Kg)
Belgium	22,500 - 27,000	2,500 - 3,000
Brazil	15,000 - 50,000	500 - 2,000
Canada	≥ 33,000	≥ 5,300
Chile	30,000	3,000
Colombia	3,180 - 7,950	480 - 1,200
Denmark	25,200	
Ecuador	20,000 - 30,000	2,000 - 4,000
El Salvador	15,000	
Guatemala	15,000 - 50,000	
Honduras	35,000	1,500
India	≥ 30,000	
Indonesia	25,000 - 35,000	2,500 - 3,500
Malaysia	25,000 - 35,000	2,500 - 3,500
Mexico	20,000	2,000
Netherlands	≥ 20,000	≥ 3,000
Panama	20,000	1,500
Peru	30,000	3,000
Portugal	18,000	
Singapore	≥ 28,300	≥ 2,200
Sweden	≥ 30,000	≥ 3,000
Taiwan	≥ 45,000	
Turkey	20,000	1,000
U.S.A.	33,000	2,080
UK	24,000 - 30,000	2,800 - 3,520

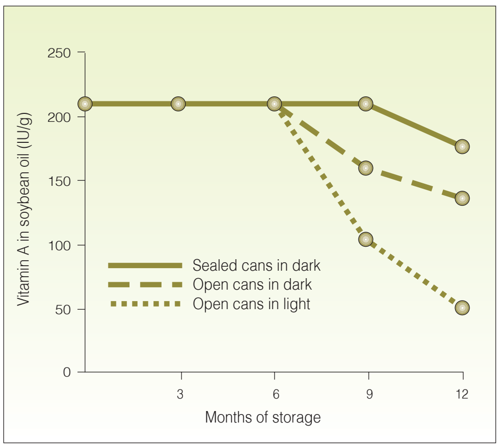
Source: Raunhardt, O. and A. Bowley. Mandatory Food Enrichment. Nutriview. Supplement to 1/1996 Issue.

Figure 2
Flow Chart of Fortified Margarine Manufacturing



Source: O'Brien, A. and D. Robertson. n.d. Vitamin Fortification of Foods (Specific Applications). The Technology of Vitamins in Foods. In Micronutrient Fortification of Foods. The Micronutrient Initiative. Ontario. Canada.

Figure 3
Stability of Vitamin A Fortified Soybean Oil During Storage at 23°C Under Different Conditions



Source: Favaro, R., J. Ferreira, I. Desai, and J. Dutra de Oliveira. 1991. Studies on Fortification of Refined Soybean Oil with All-trans Retinyl Palmitate in Brazil: Stability During Cooking and Storage. J. Food Comp. Anal. 4: 237-244.

that for cholecalciferol (vitamin D3) varies between 480 and 5,300 IU/Kg. A 15 g serving (1 tablespoon) of these margarines would provide between 4 and 51 percent of the recommended daily intake (RDI; FAO/WHO 1988) for vitamin A, and between 2 and 20 percent of the RDI for vitamin D for pre-school children.

As a nutrient, it would be appropriate to fortify oil and margarine with vitamin E at a level of 65 to 190 mg/Kg. The recommended daily intake for vitamin E increases with intake of PUFA. At a ratio of 0.4 mg α- tocopherol to 1 gm PUFA, there is enough vitamin E in normal circumstances to counteract the level of PUFA normally being consumed to prevent oxidation. At a level of 65 to 190 mg/Kg, 1 tablespoon of oil or margarine/day would provide between 15 and 50 percent of the RDI for a child between 1 and 6 years old.

The level of fat soluble vitamins in fortified oils and margarine depends on consumption patterns and nutritional requirements. Clearly, before determining the level of nutrient to add to oils and fats, the use of and consumption patterns for oil by different socio-economic and age groups need to be determined in order to ensure that the maximum safe level of intake for each nutrient is not exceeded.

Technology

The most common commercial vitamin A and D3 blend used contains 1,000,000 IU vitamin A palmitate (300,000 mg/g) and 100,000 IU vitamin D3 (2,500 mg/g) in a liquid form, stabilized with vitamin E (α-tocopherol) or a BHA/BHT mixture. The same vitamin A/D blend is also available with vitamin E fortificant (vitamin E acetate) as a custom-made premix.

Fortification of vegetable oil

Oil fortification consists of adding appropriate amounts of vitamin A and D3 concentrate to clarified, degassed oil at 45-50°C. The solubility of commercially available vitamin A and D3 blends in vegetable oils is excellent.

To ensure that the vitamins are uniformly distributed, mixing takes place in vertical tanks that contain turbines or propeller agitators. Edible antioxidants (BHA and/or BHT) or natural antioxidants (e.g. α-tocopherol or ascorbyl palmitate) may be added to protect both the vitamin A and the oil; the stability of vitamin A in the oil depends greatly on the stability of the oil itself. Vitamin A oxidizes faster and loses its activity in the presence of oxidized oils.

To maintain vitamin A activity, fortified oil needs to be packaged in light-protected, sealed containers. Replacing the container headspace with inert gas will help retain the stability of both the oil and vitamin A prior to the container being opened, but this is not usually a practical solution and adding an adequate micronutrient overage may be considered as an alternative.

The production and fortification of margarine is carried out in a batch or continuous process. The vitamin A and D3 blend is premeasured according to the batch size of the margarine tanks and mixed with warm oil, in a ratio of 1:5, until a uniform solution is obtained. This premix is then incorporated into the margarine before the emulsifying process (Figure 2). ß-Carotene is also added to margarine (15 to 20 g/ton of a 30% oily suspension) before the emulsification step to enhance the color as well as to contribute to the vitamin A content of the product. ß-Carotene converts to vitamin A at a mean level of 555 IU/mg; thus, providing an additional 2,498 to 3,330 IU of vitamin A per kilogram, at the above mentioned level.

Stability of Micronutrients

Stability of vitamin A in storage

Studies conducted in Brazil showed that the stability of vitamin A, in fortified soybean oil stored at room temperature (23°C), depends on the presence of oxygen and light (Figure 3). The stability of vitamin A in oil, stored in sealed cans, is excellent after 9 months. However,

if the oil is stored in open containers, where it is exposed to both oxygen and light, the vitamin A becomes unstable after 6 months and just under 50 percent of the initial vitamin A remains after 9 months. Stability studies in India showed almost 100 percent retention of vitamin A in fortified soybean oil after 5 months of storage in sealed cans.

Vitamin A added to margarine is quite stable during the manufacturing process and during storage at home. Table 3 shows that there were minimal losses of vitamin A in margarine after 6 months of storage at 5°C (refrigeration conditions). When the same margarine was stored at 23°C, more than 85 percent of the initial vitamin A was retained after the same period of time.

Stability of vitamin A during cooking

The stability of vitamin A in fortified soybean oil added to plain rice or kidney beans during cooking is good (Table 4). Boiling rice and pressure cooking kidney beans did not destroy the vitamin.

Frying, however, can destroy vitamin A. The amount lost depends on the number of times the same oil is used for frying foods (Figure 4). After the initial frying about 65 percent of the original vitamin A remained, after 4 repeated fryings less than 40 percent of the original levels of vitamin A was retained, and after 12 consecutive fryings most of the vitamin A was lost. Thus, how oil is used at the household level needs to be considered in determining whether oil can be a good vehicle for vitamin A.

Vitamin A losses in margarine occur under extreme conditions. Heating it to 160°C, 180°C, or 200°C for one-half hour results in average vitamin A losses of 20, 35, and 50 percent, respectively. Vitamin A, however, survives the baking process in biscuits, cakes, and breads prepared with vitamin A fortified margarine; between 80 and 100 percent of the added vitamin remains.

Stability of vitamin D_3

The stability of Vitamin D_3 is similar to that of vitamin A; little or no loss is experienced during processing or storage.

Stability of vitamin E

Vitamin E losses occur during prolonged heating, such as frying. Furthermore, the production of hydroperoxides during frying accelerates the degradation of vitamin E.

Acceptability of Fortified Margarine and Oils

Fortifying margarine with vitamins A, D, and E does not alter its flavor, making it an excellent carrier for these micronutrients. Foods made with fortified soybean oil including mayonnaise, fried beans, cooked rice, fried potatoes, soup, wheat tortillas, and fried meat showed excellent acceptability among consumers, who were not able to distinguish between products prepared with either vitamin A fortified or unfortified oil.

Studies in humans have shown that the bioavailability of vitamin A in cooked foods, made with fortified soybean oil, is good (Figure 5).

Quality Control

Determination of vitamins A, D, and E in oil and margarine is done by HPLC. This method is based on the separation of the specific vitamins from other substances that absorb radiant energy at an equal or similar wavelength to the specific vitamin. It is accurate, but the equipment is expensive and highly trained personnel are required.

Measuring the amount of micronutrients to add, and the process of their addition to oil or margarine, requires careful attention to ensure that the final fortified product is both homogeneous and standardized.

Table 3
Retention of Vitamin A in Commercial Margarine

Brand	Initial Level (IU)	After 6 Month Storage at 5°C	After 6 Month Storage at 23°C
A	13,900	14,700	13,600
B	14,200	13,400	12,700
C	13,500	12,400	11,500
D	12,300	12,100	12,300
E	12,400	12,100	10,900

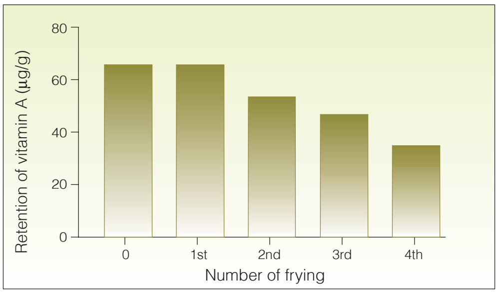
Source: Bauernfeind, J.C. 1978. The Technology of Vitamin A. Hoffmann-La Roche. Basel, Switzerland.

Table 4
Stability of Vitamin A in Soybean Oil During Cooking

Food	Type of cooking	Amount of Vitamin A (µg/g) Before cooking	Amount of Vitamin A (µg/g) After cooking	Recovery (%)
White rice	Boiled	330	330	100
Kidney beans	Boiled	180	150	83
Kidney beans	Pressure cooked	120	120	100

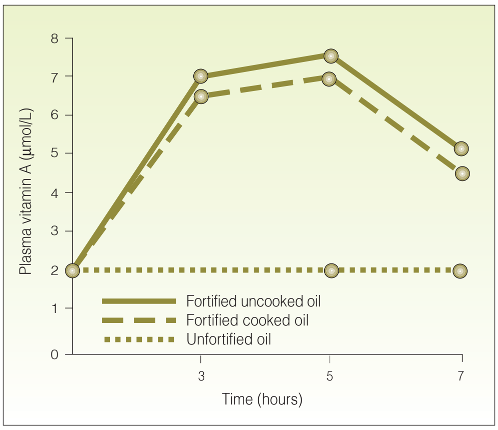
Source: Favaro, R., J. Ferreira, I. Desai, and J. Dutra de Oliveira. 1991. Studies on Fortification of Refined Soybean Oil with All-trans Retinyl Palmitate in Brazil: Stability During Cooking and Storage. J. Food Comp. Anal. 4: 237-244.

Figure 4
Stability of Vitamin A in Fortified Soybean Oil After Repeated Fryings of Potatoes at 117-170°C.



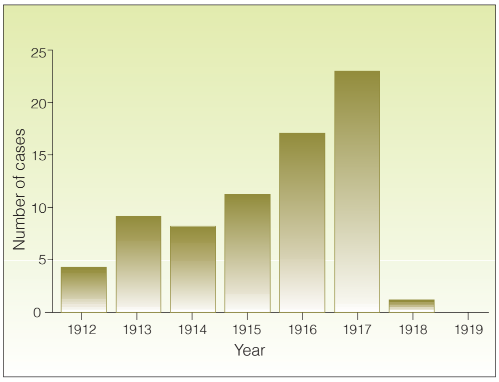
Source: Favaro, R., J. Ferreira, I. Desai, and J. Dutra de Oliveira. 1991. Studies on Fortification of Refined Soybean Oil with All-trans Retinyl Palmitate in Brazil: Stability During Cooking and Storage. J. Food Comp. Anal. 4: 237-244.

Figure 5
Serum Retinol levels in Humans After Ingestion of Cooked and Uncooked Fortified Oil with Vitamin A



Source: Dutra de Oliveira, J.E., I. Desai, R.M.D. Favaro, and J.F. Ferreira. 1994. Effect of Heat Treatment During Cooking on the Biological Value of Vitamin A Fortified Soybean Oil in Human. Int. J. Food Sci. Nutr. 45: 203-207.

Figure 6
Distribution According to Year of Appearance of Xerophthalmia in 72 Patients Admitted to the Rigshospital, Copenhagen from 1912 to 1919



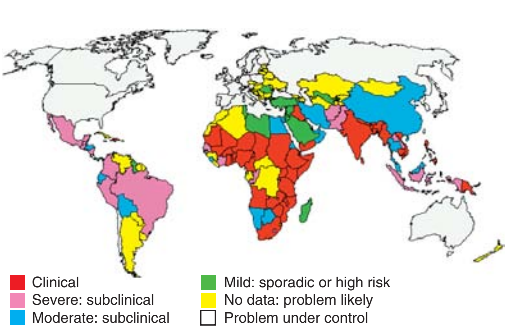
Source: Bloch, C. E. 1931. Effects of Deficiency in Vitamins in Infancy. Am. J. Diseases of Children. 42: 271.

Table 5
Vitamin A Deficiency in Newfoundland in 1944 and 1948

	1944	1948
Number of subjects	312	342
Percent of subjects with		
serum vitamin A < 20 µg/dl	48	2
serum vitamin A < 30 µg/dl	74	18
Mean serum vitamin A (µg/dl)	22	41

Source: Aykroyd, W.R. et al. 1949. Medical Resurvey of Nutrition in Newfoundland 1948. Murray Printing Company. 11-12.

Countries Categorized by Degree of Public Health Importance of Vitamin A Deficiency



Source: WHO XVII IVACG Meeting, Guatemala,1996.

Costs

The cost of fortification includes capital costs, such as blending equipment (tanks, propellers, or agitators), and recurrent costs including those for the premix, personnel, and monitoring and evaluation.

If margarine is fortified to provide 30,000 IU of vitamin A/Kg, the cost of the fortificant would be in the order of US$ 0.0020/Kg when a vitamin A/D_3 blend is used. The cost of vitamin A alone is around US$ 0.0017/Kg of product. These estimates do not take in account the cost of new equipment and training of staff, which are one-time costs and are likely to be small, as well as the cost of quality control.

Legislation

To ensure that a fortification program is successful, an interdisciplinary task force with experts from the different, appropriate sectors should be set up. The sectors include the vegetable oil industry and trade organizations, nutrition institutes, universities, the Ministry of Health, regulatory institutions, consumer associations, and donors.

A fortification plan should specify the type of micronutrients and levels to be added based on the consumption patterns of oil by different socioeconomic and age groups. It must also define precautions and food safety conditions to be observed during production, transportation, storage, and sale of the products.

History and Successful Interventions

The prevalence of xerophthalmia in Denmark declined drastically in 1918 and disappeared in 1919 (Figure 6) following the introduction of butter rationing (which made butter available at a low price and diminished consumption of non-enriched margarine) at the end of 1917. Xerophthalmia reappeared in 1920 when butter rationing was discontinued; thus, eliminating access to an important source of natural vitamin A. Such observations on the curative effects of milk fat, but not of margarine, eventually led to the enrichment of margarine with vitamin A.

A successful intervention with vitamin A fortified margarine (45 IU vitamin A/g margarine) initiated in Newfoundland in 1944-45, led to a marked improvement in the vitamin A status, as shown by biochemical measurements made in a sample of the population (Table 5).

Thirty years ago, Pakistan agreed to fortify processed oil products with vitamin A at a level of 33,000 IU/kg. Enforcement and monitoring has been weak as reflected in the levels of vitamin A in vegetable ghee, which were on average 15,000 IU/kg. With an average vegetable ghee consumption of 30 g/person/day, the ghee would provide about 30, 24, and 15 percent of the RDI for infants, children, and pregnant women, respectively.

In the Philippines, a collaborative effort between the public and private sectors resulted in the “Star” brand margarine being fortified with vitamin A. “Star” margarine is fortified at a level of 25 µg RE/g (83 IU), and provides 95 percent of the RDI for children 1 to 10 years old when 15 grams/day (1 tablespoon) is consumed. Other countries fortifying margarine with vitamins A and D are presented in Table 2.

Sweden fortifies canola oil used in food aid programs with 15 mg vitamin A/g oil. Canada has adopted an even higher level of 22.5 mg vitamin A/g canola oil used in food aid programs.

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